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DESIGN OF INTERNET OF THINGS (IOT) BASED HYDROPONIC CONTROLLING DEVICE IN PYRAMID GREENHOUSE

Arif Umami[1*], Bagus Muhammad Akbar[2]
[1]Department of Agrotechnology, Faculty of Agriculture
[2]Department of Informatics, Faculty of Industrial Technology
Universitas Pembangunan Nasional Veteran Yogyakarta
**Corresponding author:* arif.umami@upnyk.ac.id

Abstract

Smart farming technology was previously implemented at Wedomartani experimental station, Faculty of Agriculture UPN "Veteran" Yogyakarta. It is proven to overcome human resource limitations in hydroponic cultivation. Even so, Smart farming has not been implemented yet in Pyramid Greenhouse, Which is the iconic landmark of the Faculty of Agriculture. Preparing IoT-based devices requires designs with certain specifications. Without an appropriate design, it would be found a failure system. This article's purpose was to design an Internet of things (IoT) based hydroponic controlling device in Greenhouse Pyramid UPN "Veteran" Yogyakarta. It was built based on a literature study. Expert proofing was performed to ensure the design would work if implemented. The design contained the system overview, hardware description, user interface design, and integration of device system design in hydroponic installations. The design was positively accepted by users (Head of the experimental field and technicians). In the future, the proposed design needs to be realized as a part of greenhouse development.

Keyword: *Design, Internet of things, Hydroponic, Controlling device*

INTRODUCTION

In the digital era, smart farming optimizes complex farming systems to support farmers in decision-making. The scope of smart farming includes the internet of things, sensors, location-based systems, robotics, and artificial intelligence (Wolfert et al., 2014; Sundmaeker et al., 2016). Controlling devices based on the Internet of Things (IoT) is an example of smart farming management that could optimize the performance of the hydroponic system. Internet of Things (IoT) is a term that appears with the notion of access to electronic devices through internet media. Access to these devices occurs due to human-devices relation or devices - devices by utilizing the internet network. Its access occurs because the desire for data sharing also considers access security (Wasista, 2019). In other words, the IoT is a system that connects a device with other devices through the internet.

Smart farming technology was previously implemented at Wedomartani experimental station, Faculty of Agriculture UPN "Veteran" Yogyakarta. It is proven to be able to overcome human resource limitations. Even so, it has not been implemented at pyramid Greenhouse, the iconic landmark of the Faculty of Agriculture. The pyramid greenhouse is a greenhouse for lecturers and students to research hydroponics and orchid cultivation. Apart from that, the greenhouse has become a place for visiting guests from both academics and communities. Until now, hydroponic cultivation in pyramid greenhouses still uses a conventional system by measuring TDS and pH manually in nutrients. The results of measurements are needed to provide suitable nutrients for hydroponic plants by adjusting pH and TDS frequently. Sometimes, plants get inappropriate nutrition because of an adjustment delay. Thus, Hydroponic management that has not been optimal has an impact on not optimal production of hydroponic plants. An IoT-based device that could optimize nutrition conditions is needed to answer that problem. Previously, an IoT-enabled system to monitor and control the greenhouse was proposed by Kumar et al. (2020). This system successfully controls various parameters like temperature, humidity, and soil moisture level. Preparing IoT-based devices requires designs with certain specifications so that the assembled tools run according to plans and objectives. Even so, until now, the design that fits the pyramid greenhouse has not been realized. Therefore, this paper will discuss the device's design that allows it to be used and followed up to increase the implementation of smart farming at pyramid greenhouse.

METHODS

Literature Study

The design was compiled through a literature search which included an overview of the system, hardware description, user interface design, and integration design in hydroponic installations. All design images were created using Canva.

Expert Proofing and User acceptance

The device's design was validated by experts descriptively using a questionnaire. Meanwhile, user acceptance was measured qualitatively through an interview.

PROPOSED WORK

System overview

The general description of the system from the designs is that users could access the system using the Android application (user interface) to monitor and control nutritional parameters and environmental conditions. The android application is connected to the cloud firebase database or IoT server for data storage media as data collection and processing in hydroponic cultivation. Data from the server is then sent to the device (Hardware device). Likewise, environmental data and fertilizer nutrition will be sent to the server.

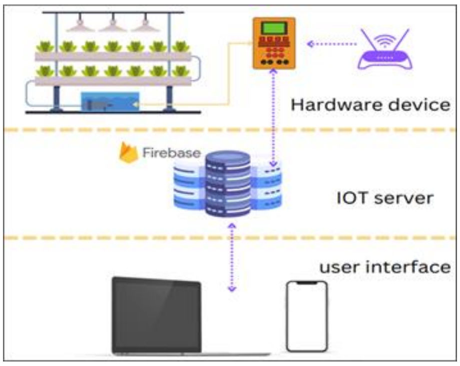


Figure 1. System Overview

Hardware Description

Hardware is all kinds of components on a computer that have a physical form. So, the hardware is a physical device for carrying out several processes, such as input, output, and processing. The Hardware functions are for data or information processing, receiving output, giving output, and eliminating information and data.

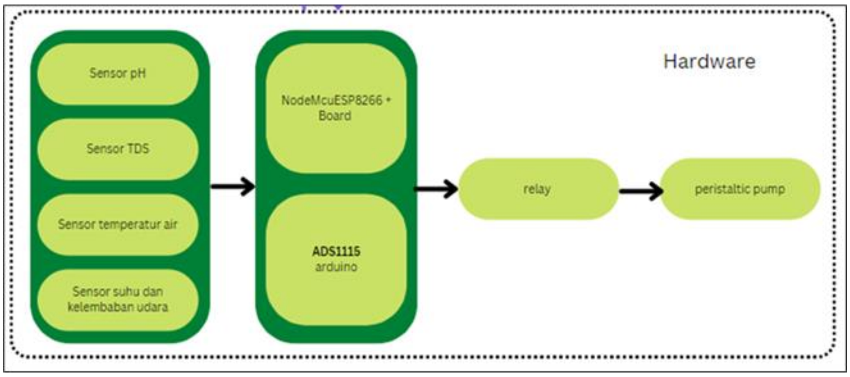


Figure 2. hardware schematic diagram

The schematic diagram (figure 2) showed the electronic circuits that connected the microcontroller to sensors and other supporting devices. The electronic circuit is presented in Figure 3. The main components are as follows:

A. NodeMCU

NodeMCU is a microcontroller equipped with an ESP8266 WIFI module, so NodeMCU is the same as Arduino, which is suitable for IoT projects. This version is a development of version 0.9. Moreover, in version 1.0, the ESP8266 used is the ESP-12E type, considered more stable than ESP-12. In addition, the size of the module board is reduced so that it is compatible with making project prototypes on breadboards. There are special pins for SPI (Serial Peripheral Interface) and PWM (Pulse Width Modulation) communication, which are unavailable in version 0.9. NodeMCU board sends data to the server smoothly. All sensor data is sent properly to the

Thingsboard server by displaying data in charts and graphs (Karim, et. al., 2021).

B. ADC (Analog To Digital Converter)

ADC (Analog To Digital Converter) is an electronic device that converts analog signals into digital signals. The ADS1115 ADC module is a module that is enabled for Analog Digital Converter (ADC) reading with I2C communication with a resolution of up to 16-bit, which has four channels. It is functionally easy to use with the measurement of a wide range of signals over a voltage range from 2v to 5v, and it is suitable for measurements with 16-bit resolution. This module must use the NodeMCU ESP8266 module because there is only an ADC.

C. Relay

A relay is a multi-purpose electronic device as a voltage source breaker if there is a short circuit or fire or if there is damage to the electronic device so that the electronic device is not directly damaged. It is a component or switch device that operates using electricity. It consists of two main parts: the coil and the switch or mechanical contacts. The relay's functions are a) to set up a high voltage electronic circuit with the help of low voltage signals, b) to execute the function of a logic gate, namely the NOT logic gate, c) to set the time delay function, and d) to protect the motor or other components from overvoltage or short circuit.

D. pH sensor

SEN0161 is a type of sensor that has a function to calculate or measure the pH value or degree of acidity of a liquid, especially the pH value of water. The value of the pH sensor reading is in the range of 0-14. This module consists of the Liquid pH 0-14 Value Detect Test Sensor Module and the pH Electrode Probe Hydroponic Sensor BNC Interface (shaped like a marker at one end, and another end is the BNC jumper). The sensor's working principle is that when the sensor's lower part is inserted into the solution, the sensor will produce analog data (ADC). It will then be converted into a pH value with calculations determined in the program.

E. TDS sensor

It is an Arduino-compatible sensor that measures TDS (Total Dissolved Solid) levels in the water. TDS itself is the level of concentration of solid objects dissolved in water. The higher the TDS value, the more water turbid, and vice versa.

F. Temperature and humidity sensors

The DHT sensor is a sensor package that measures air temperature and humidity at the same time. There is a thermistor type NTC (Negative Temperature Coefficient) to measure temperature and a humidity sensor with resistive characteristics to changes in moisture content in the air. A chip does several conversions from analog to digital and outputs in a single-wire bi-directional format. A system with a DHT sensor could control a temperature of 23-29^{o}C and a humidity of 60-80% (Nuswantara, et al., 2018). In addition, temperature and humidity sensors of the DHT22 type were very suitable when used as a monitoring tool for plant growth (Endryanto and Khomariah, 2020).

User Interface (UI) Design

The hydroponic controlling system requires an android mobile app (.apk), then the results will be stored in databases (Shrivastava et al. 2021). For commercialization, a vendor is needed to build and maintain. In addition, it also requires the development of dashboards for admins as Web-based developers, which is not elaborated on in this article. Application vendors are responsible for building applications and facilitating uploads to Playstore. In addition, the same Vendor could also play a role in providing or facilitating IOT cloud servers. Meanwhile, the team of Faculty could send icons, formulas, and process flow at the UI design stage of the application.

UI is the visual part of a website, application, software, or hardware that determines how a user interacts with the product. UI design combines the concepts of visual design, interaction design, and information infrastructure to increase the ease of use of a product. As a visual element of a product, the purpose of making a UI is to provide ease of usability of the product. Visual elements such as layout, buttons, icons, images, text, and color choices in a product are part of the UI.

a b C d e

Figure 3. User Interface Design a) Booting b) Online Mode c) Offline Mode d) Automatic Setting e) Manual Setting

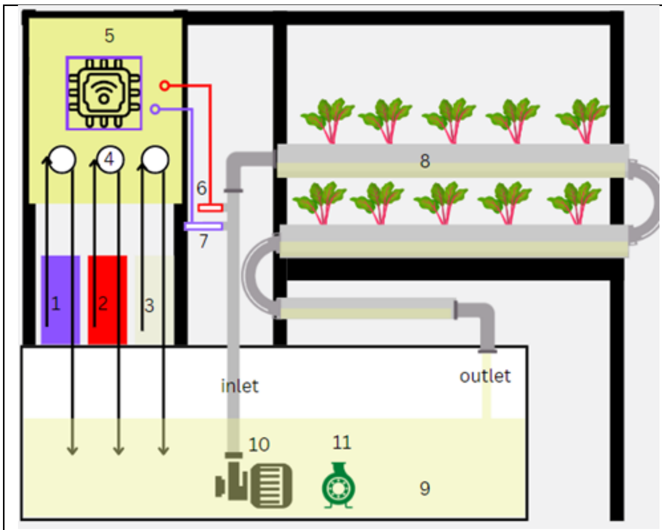
Good UI design will make it easier for interaction between users and products. With an easy interaction experience, users will be more loyal to using the product because their needs and goals can be met. UI display plan for the smart

Vanda application (smart farming Veteran Hydroponic Yogyakarta) when booting after being successfully installed on Android is shown in figure 3a. After successfully logging in then, the display appears.

In operation, two conditions might occur (figure 3b and 3c): the system is in an Online or Offline state. When the system conditions were online, users could see the parameters such as air temperature, humidity, TDS, and pH. In addition, users could also get a fluctuation historical graph of TDS and temperature. Meanwhile, an offline status would appear when the system had no internet connection, indicated by all parameters show no numbers. Graphics and peristaltic pumps icons also became inactive. On the other side, automatic mode (Figure 3d) was prepared for users' insufficient information about the TDS and pH needed by plants. Plants species with the appropriate pH and TDS were provided. It was also designed to manually operate pumps connected to fertilizers, pH regulators, and reservoirs (water volume regulation). Manual settings are useful when there is a discrepancy between the numbers read by the sensor and the real conditions (Figure 3e).

Integration of Device System Design in Hydroponic Installations

It is necessary to arrange the integration of the controlling system device with the hydroponic installation. The proposed device could then be assembled according to figure 4. The controlling device is packed in a box to protect the components from external disturbances.



Caption
1. Concentrated Fertilizer A
2. Concentrated fertilizer B
3. Down pH
4. Peristaltic pump
5. Microcontroller
6. pH sensors
7. TDS Sensors
8. Hydroponic Pipe
9. AB mix fertilizer container
10. main pump
11. aerators

Figure 4. Nutrition Controlling Systems in Hydroponic Installations

The pH and TDS sensors are installed on the nutrient inlet pathways (figure 4) before they reach the plants. So, the nutrient levels read by the sensors are the nutrients the plants will receive. Conversely, if it is installed in the output line, the nutrient levels will be biased, and the time needed to increase TDS levels is predicted to take longer. Furthermore, peristaltic pumps are installed close to the pH and concentrated fertilizer container so that the pump could immediately withdraw liquid and pump it into the main container when TDS and pH values had changed. The main pump is always installed in a submerged condition. In addition, it is also equipped with an aerator to add oxygen to the liquid fertilizer. Oxygen is needed by plant roots for the respiration process.

Expert proofing and Users acceptance

Designs required validation from experts. The higher the score, the design was according to specifications and recommended to be realized. Assessment aspects and descriptors are shown in table 1. Results showed that the design highly recommends the next step with 48 of 50. Meanwhile, User acceptance was measured qualitatively by interviewing the Head of the experimental field and technicians. Generally, Users appreciate the design made. Moreover, one of the users' testimonials implied that the design would be included in the next greenhouse development plan.

Table 1. Assessment aspects and descriptors valued by Expert

No	**Assessment aspects and descriptors.**	**Score**				
		1	**2**	**3**	**4**	**5**
1	The design contained software by its function					√
2	The software that will be used is predicted to produce products according to the design				√	
3	The software used is predicted not to cause a system failure				√	
4	easily accessible software					√
5	The design contained a list of hardware according to its function					√
6	hardware will be predicted to work optimally					√
7	easily accessible hardware					√
8	The hardware used is predicted to be able to support the system					√
9	the design described a clear system flow					√
10	The system flow shown is predicted to run optimally					√
Score obtained		48/50				
Percentage (%)		96				

CONCLUSION

The design has been made according to specifications and validated by experts. It was positively accepted by users (Head of the experimental field and technicians). In the future, the proposed design needs to be realized as a part of greenhouse development.

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